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INT CL⁶ G01B 21/00, G01D 5/32 5/34 5/347 5/36,
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(54) **Robot cleaner direction sensor**

(57) The direction sensor of a robot vacuum cleaner comprises a permanent magnet 72 attached to a disc 76 that rotates freely on a vertical shaft 70 attached to the body of the cleaner. The disc 76 carries a circular array of reflective triangles which reflect light emitted from means 82 back to the sensing means 82. As the direction of the vehicle changes the disc rotates relative to the emitting/sensing means 82 and the output of the sensing means varies gradually and cyclically allowing the magnitude and direction of rotation to be determined.

Also disclosed is a system for sensing raised or depressed floor areas (figure 8), a system for selecting a cleaning program by determining the configuration of an area to be cleaned by initially causing the cleaner to move around the periphery of a room and a combined ultrasonic and optical navigation system (figure 9).

FIG.6a

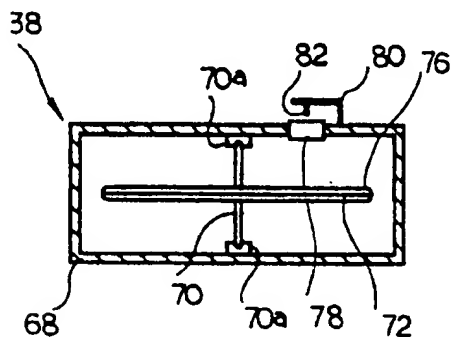
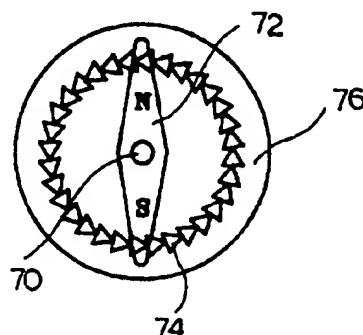


FIG.6b



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FIG. 1

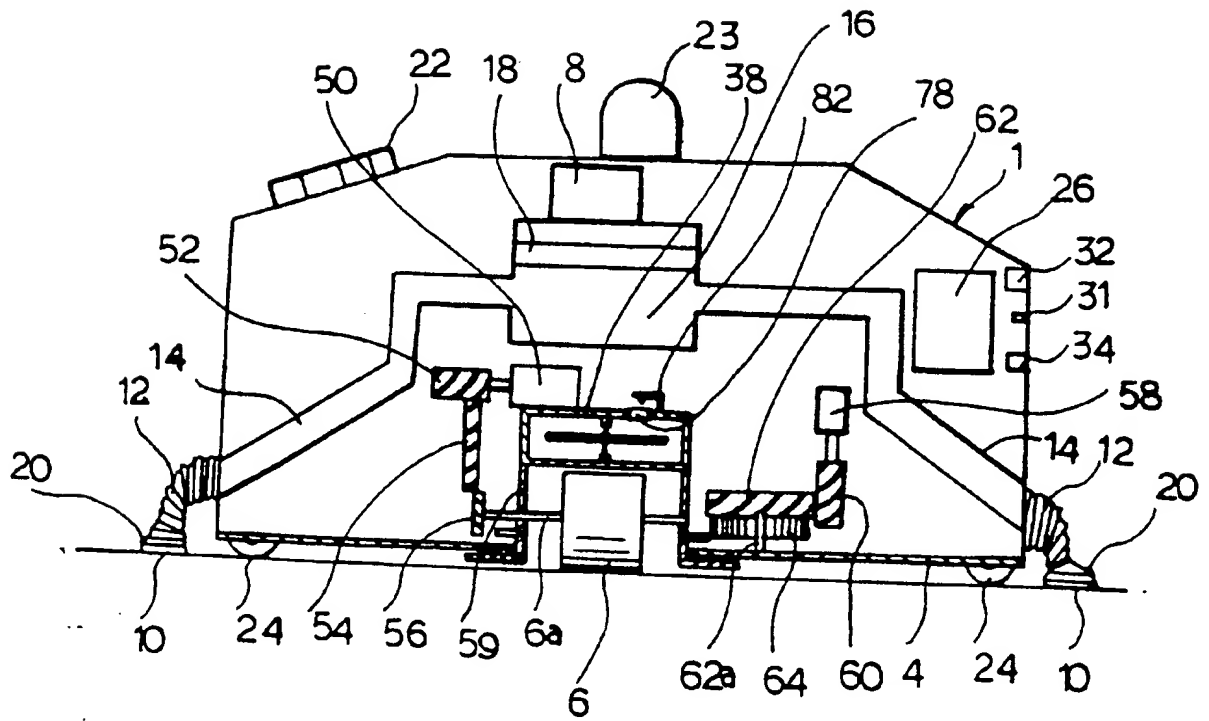
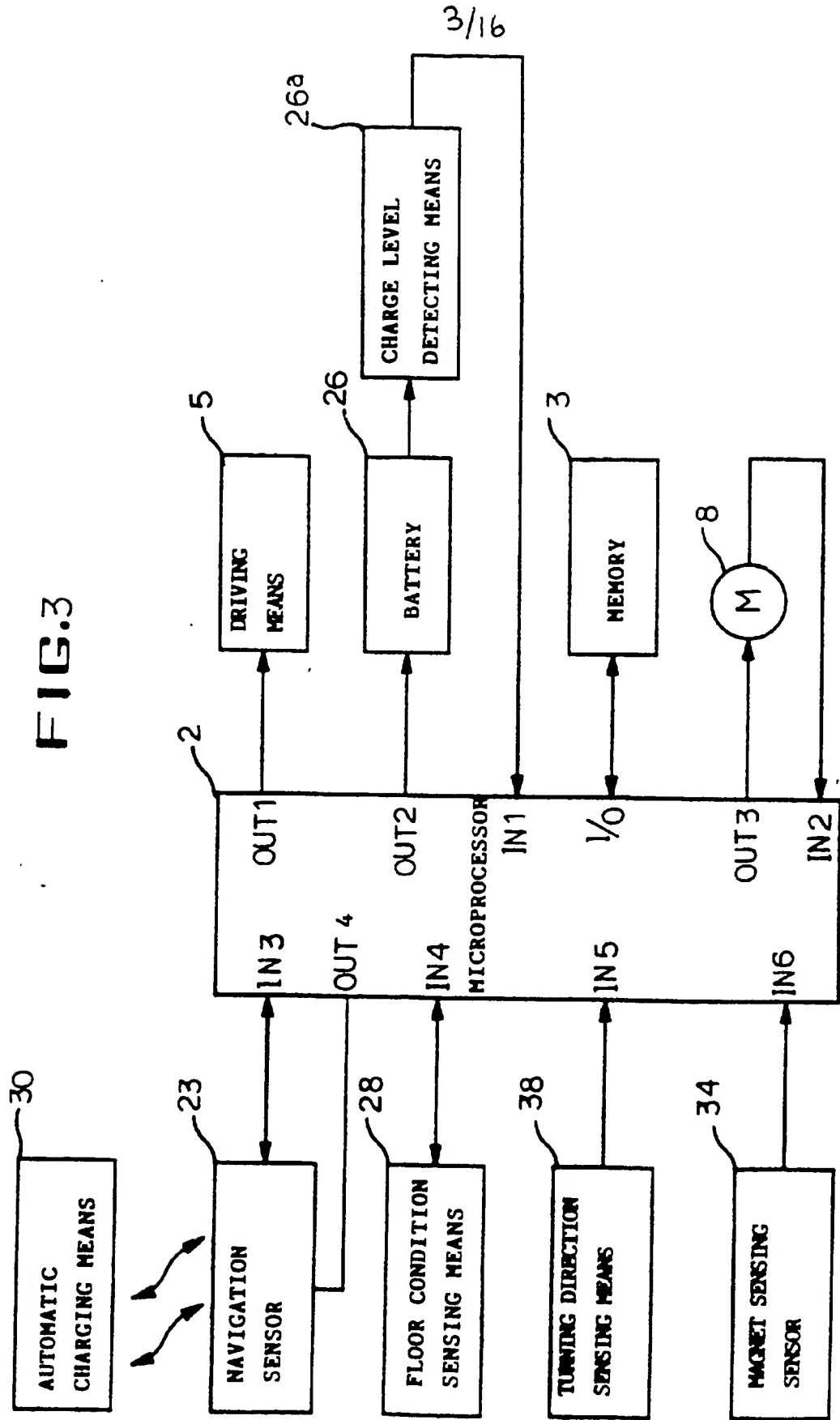


FIG. 3



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FIG. 4

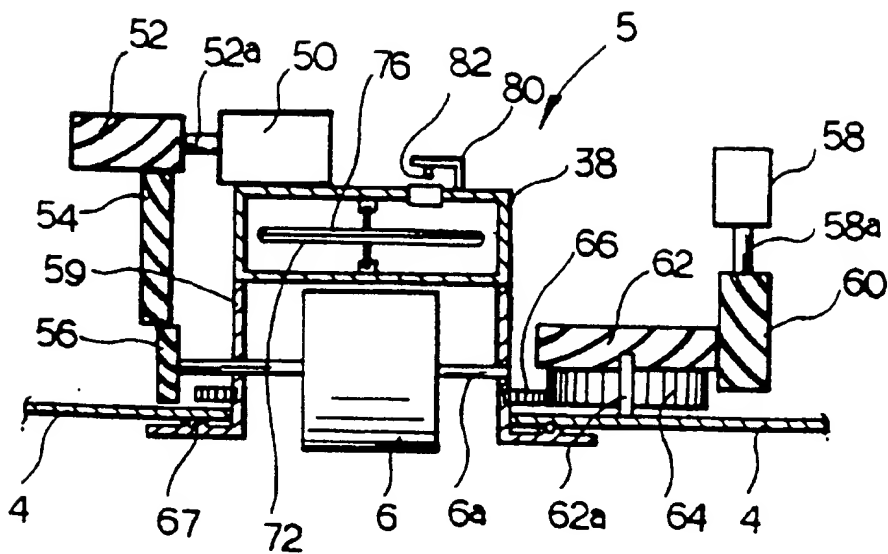
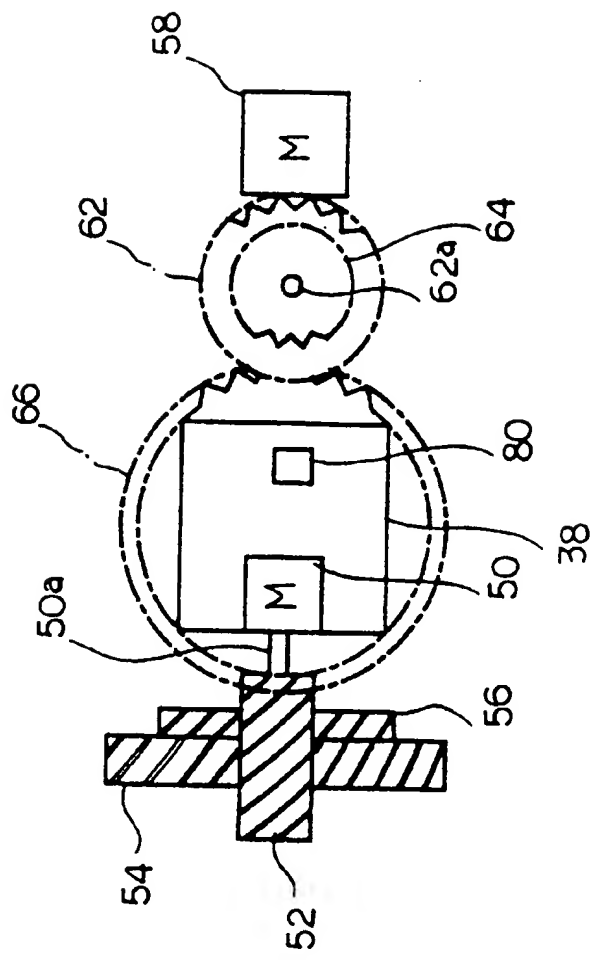


FIG. 5



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FIG.6a

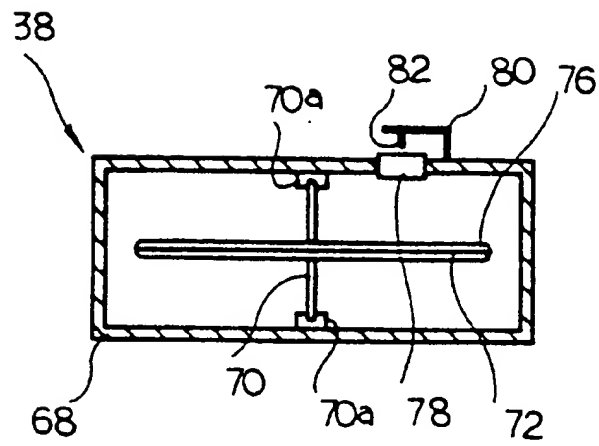


FIG.6b

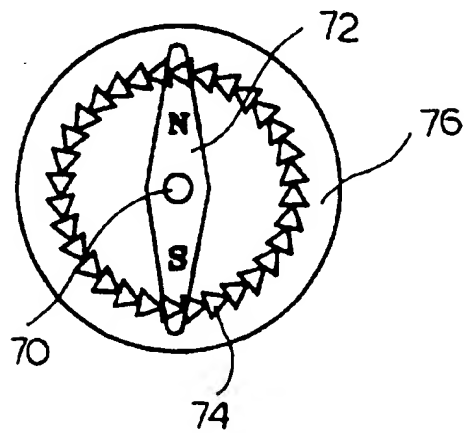
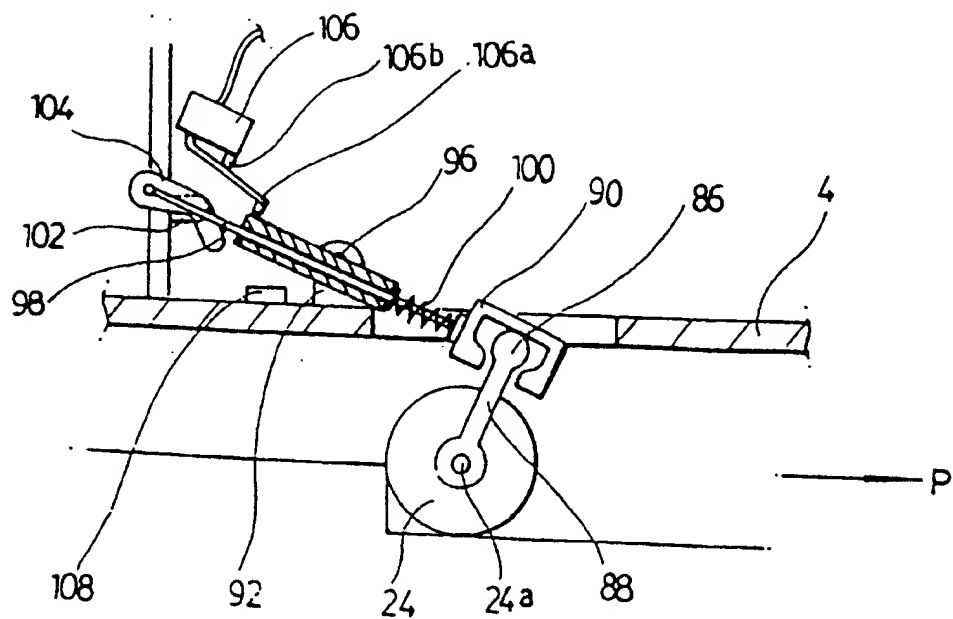
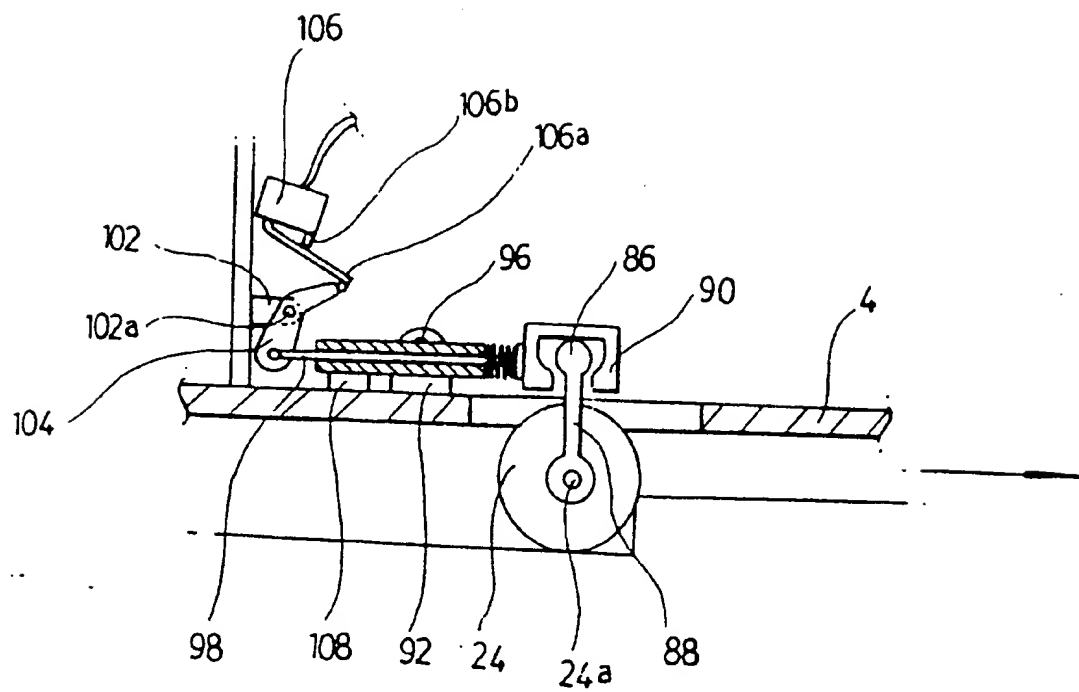


FIG 7



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FIG. 8b



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FIG. 9b

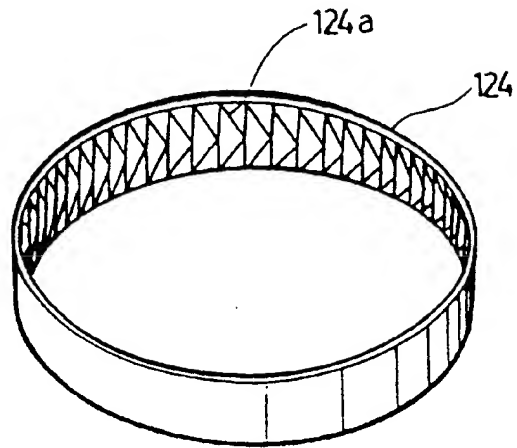


FIG. 10

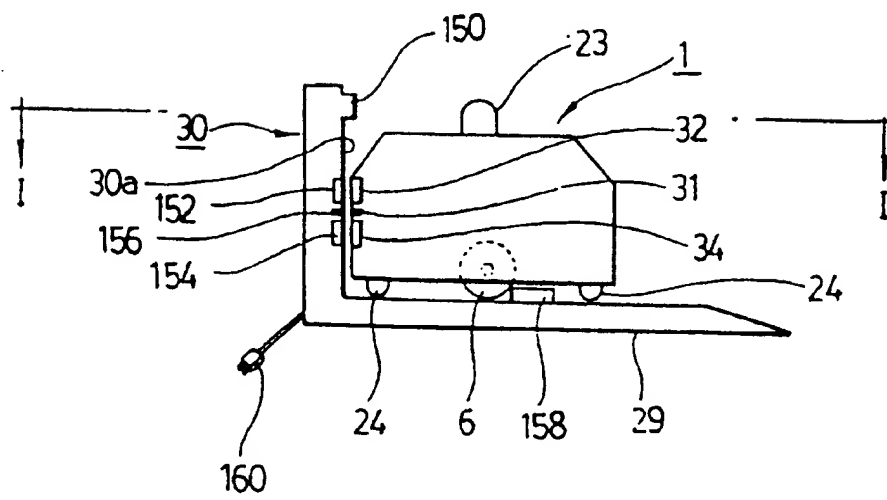


FIG.11a

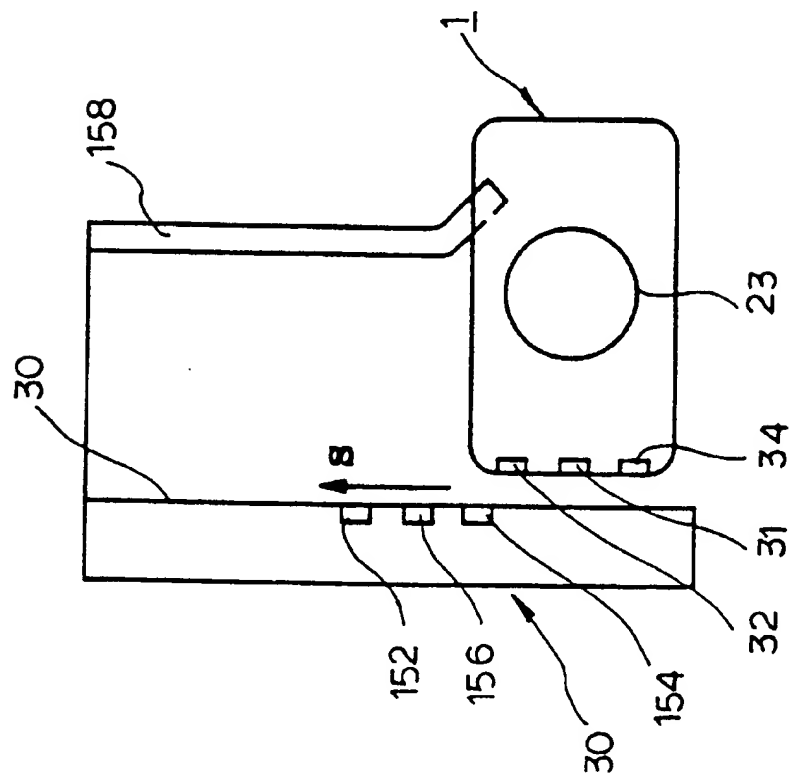


FIG.11b

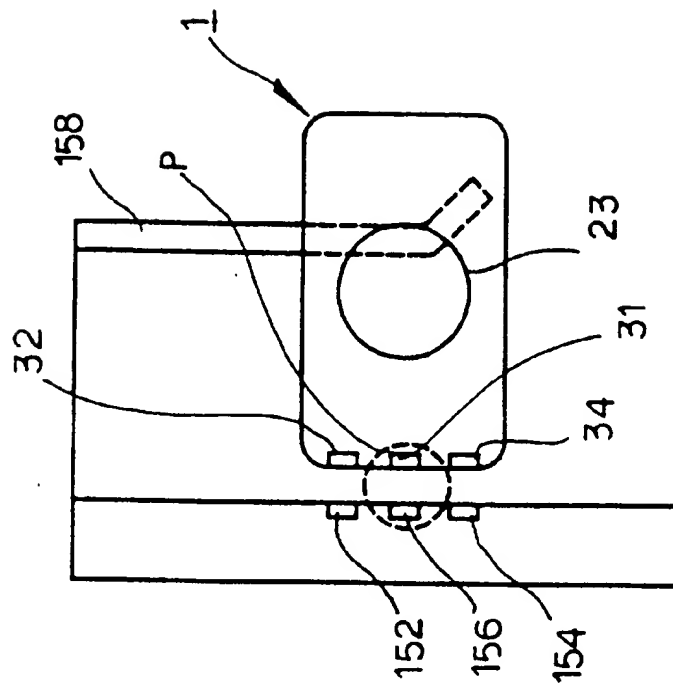


FIG. 13

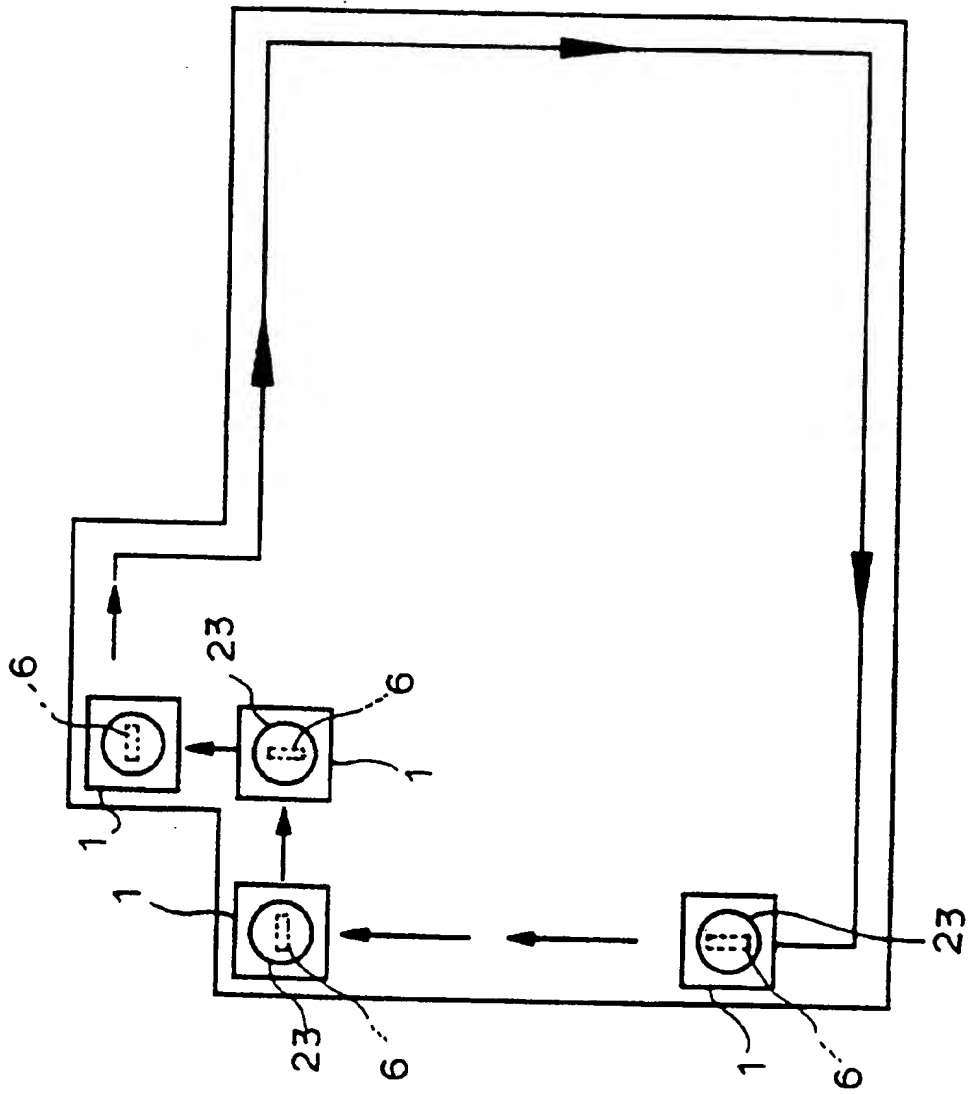


FIG.14

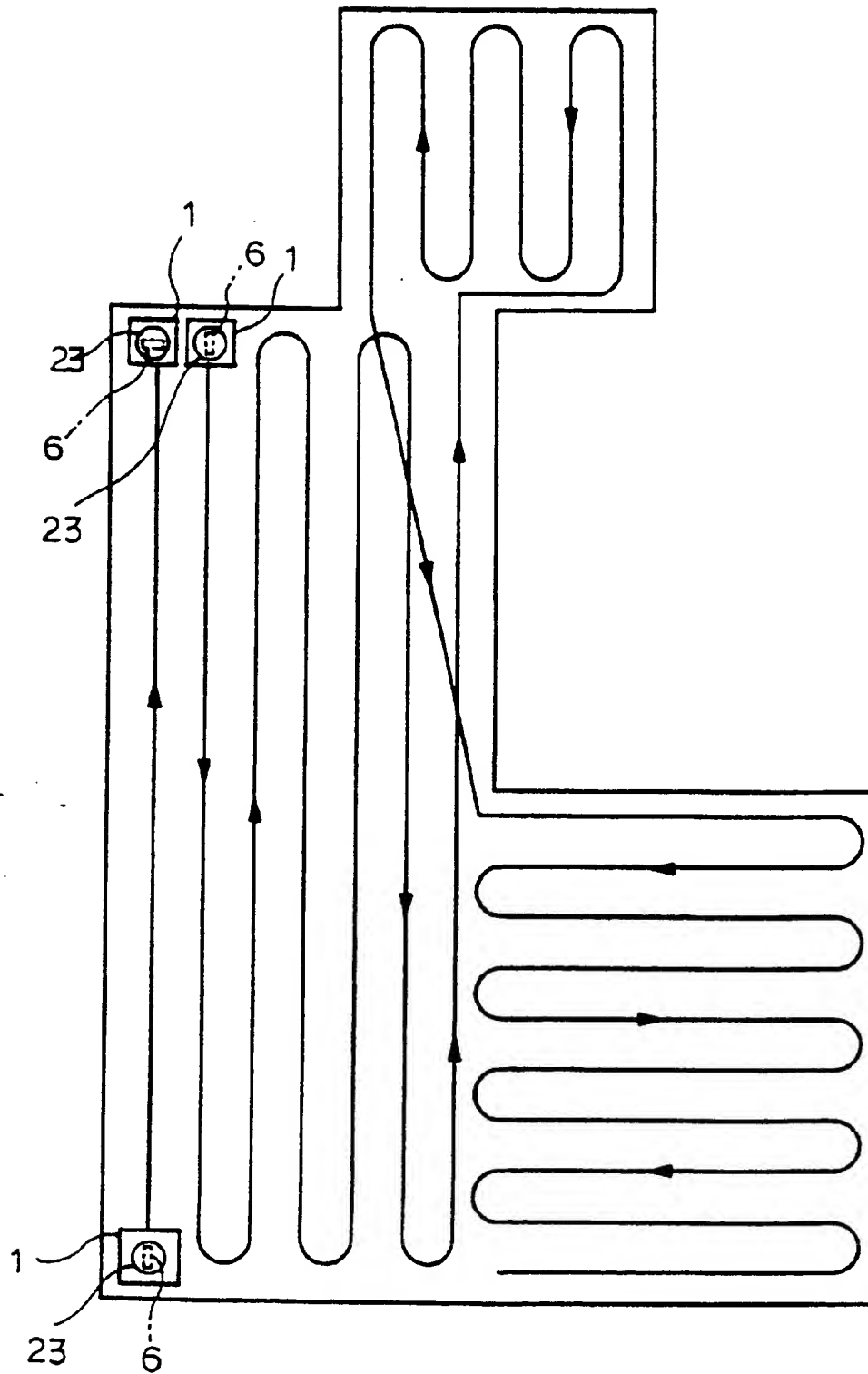


FIG. 15

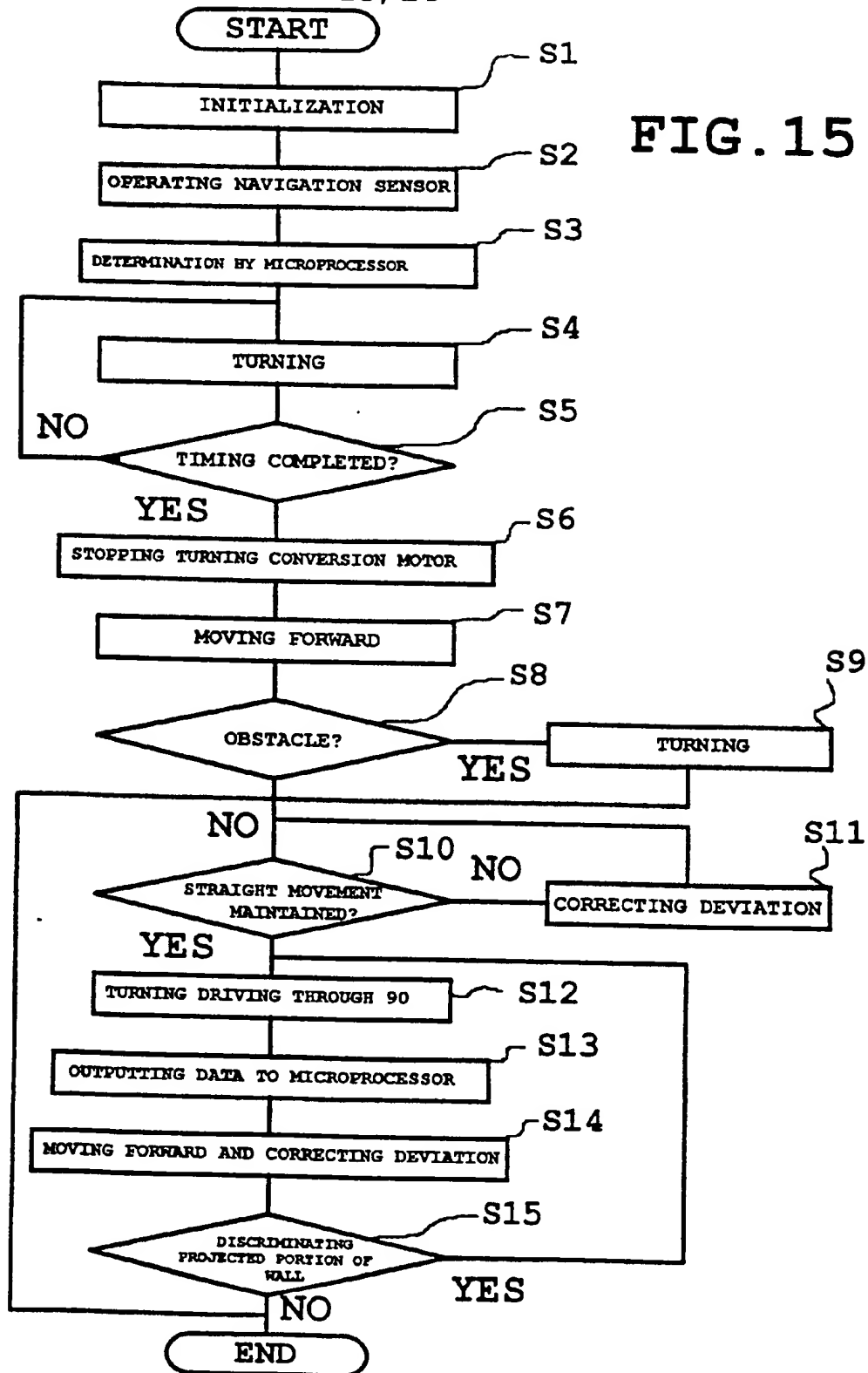
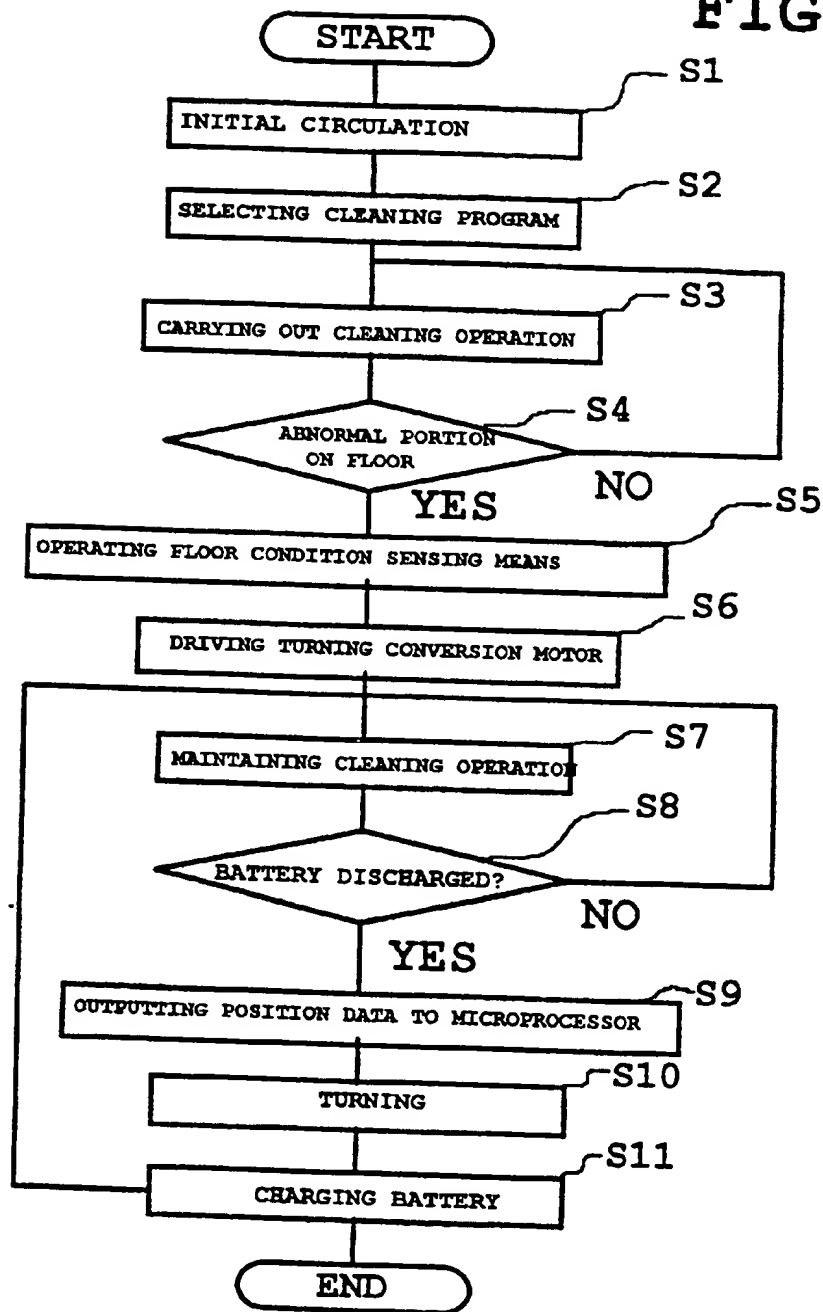


FIG. 16



ROBOT VACUUM CLEANER

The present invention relates to a robot vacuum cleaner and a cleaning system employing a robot vacuum cleaner.

5 A self-moving robot cleaner is disclosed in Japanese Patent No. Sho 58-221925. The self-moving robot cleaner disclosed in this Japanese Patent carries out a cleaning operation as follows. A high reflectivity tape is attached to a floor along a desired path to be cleaned. An optical sensor of the robot cleaner
10 shines light onto the tape and receives the reflected light from the tape in order to search out the path of the tape. Therefore, the robot cleaner can suck dust and dirt from a floor while moving along the path defined by the tape.

15 As another conventional vacuum cleaner, there is, of course, the well known manual vacuum cleaner. However, in the manual vacuum cleaner, the user must carry a nozzle for sucking dust and dirt so as to clean a wide floor and a hose for introducing dust and dirt into a dirt-collecting chamber is limited to a substantially short length. Although the manual vacuum cleaner having the
20 short hose can clean a floor without any particular problem when the floor is narrow, a canister and the nozzle of the vacuum cleaner must be frequently moved during a cleaning operation when a floor is wide.

In addition, a moving range of the vacuum cleaner is restricted by the length
25 of the power cord for connecting the vacuum cleaner to a power source. Also, when the vacuum cleaner cleans a wide floor, a plug of the power cord must be frequently plugged in power sources at different positions because the power cord is short. When a power source is not available in the vicinity of a floor to be cleaned, it is necessary to provide an additional extension cord for
30 connecting the plug to a main power source. Furthermore, since the user must carry the vacuum cleaner during the cleaning operation, the user must endure troublesome noise generated from the cleaner.

According to the present invention, there is provided a robot vacuum cleaner comprising a navigation sensor for detecting obstacles, driving means for propelling the cleaner and control means for determining a cleaning area and controlling the driving means in dependence on the output of the navigation
5 sensor.

Preferably, the vacuum cleaner includes energy storage means and means to determine the state of the energy storage means. The energy storage means may comprises a battery.

10

A rechargeable robot vacuum cleaner according to the present invention may be employed in a cleaning system including a recharging station, wherein the vacuum cleaner's control means is operable in response to the means for determining the state of the energy storage means to control the driving
15 means to move the robot vacuum cleaner to the recharging station.

Preferably, the recharging station includes a homing signal generating means for generating a homing signal and the robot vacuum cleaner includes means for detecting said homing signal.

20

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a side sectional view of a robot cleaner according to an
25 embodiment of the present invention;

Figure 2 is a plan view of the robot cleaner of the invention from which a top cover is removed;

Figure 3 is a block diagram of a control system of the robot cleaner of the invention;

30 Figure 4 is a front view of the driving means for the robot cleaner of the invention;

Figure 5 is a schematic view showing an operation of a turning conversion

gear and a turning conversion motor of the driving means of Figure 4;

Figure 6a is an enlarged sectional view of turning direction sensing means of the invention;

Figure 6b is a plan view of a reflection disc of the turning direction sensing means in Figure 6;

Figure 7 is a schematic side view of floor condition sensing means of the invention;

Figure 8a is a side view of the floor condition sensing means of Figure 7 which encounters with a depressed portion of a floor;

Figure 8b is a view similar to Figure 8a which encounters with a stepped portion of a floor;

Figure 9a is a schematic view of a navigation sensor of the invention;

Figure 9b is a perspective view of a deflective reflection collar of the navigation sensor of Figure 9a;

Figure 10 is a plan view of automatic charging means of the invention to which the robot cleaner of the invention is moved;

Figure 11a is a plan view taken along the line I-I of Figure 10 in which the robot cleaner is moved to vicinity of the charging means;

Figure 11b is a view similar to Figure 11a in which the robot cleaner is located at the precise charging position;

Figure 12 is an enlarged view of the circle P of Figure 11b;

Figure 13 shows an initial operation path of the robot cleaner according to the invention;

Figure 14 shows a cleaning operation path for the robot cleaner of the invention;

Figure 15 is a flowchart exhibiting the procedure for the initial operation of the robot cleaner of the invention; and

Figure 16 is a flowchart exhibiting a procedure for a cleaning operation of the robot cleaner of the invention.

Figure 1 shows a schematic side elevation of a robot cleaner body according to an embodiment of the invention, Figure 2 shows a plan of the robot cleaner

body from which a top cover is removed, and Figure 3 shows a block diagram of a control system of the robot cleaner.

As shown in the drawings, the robot cleaner 1 has a microprocessor 2 for
5 controlling the overall operation of the cleaner, a memory 3 for storing
driving programs for the cleaner associated with structures of various rooms to
be cleaned, and driving means 5 mounted on an underside of the cleaner 1 and
adapted to drive a driving roller 6 under a control of the microprocessor 2 in
order to cause the robot cleaner 1 to be moved forward and backward and to
10 turn left and right.

A driving shaft 6a of the driving roller 6 of the driving means 5 is supported
by a bracket 59. Disposed on the bracket 59 is a turning direction sensing
means 38. Mounted above the driving means 5 is a vacuum motor 8 for
15 sucking dust and dirt from a floor and introducing the sucked dust and dirt
into a dirt collecting chamber 16 through nozzles 10, suction ducts 12 and air
ducts 14. As schematically shown in Figure 1, the robot cleaner 1 is provided
at its upper case with a control panel 22 for controlling a drive and a stop of
the cleaner 1. Also, the robot cleaner 1 is provided at a central position of its
20 upper case with a navigation sensor 23 for detecting a presence of an
environmental obstacle and a distance to and a direction of the obstacle. Each
of four corners of a bottom plate 4 is provided with a caster 24 having floor
condition sensing means in order to sense an abnormal condition of a floor,
for example, a depressed portion and a stepped portion of the floor. A side
25 wall of the robot cleaner 1 is provided with a magnet 32, magnet sensing
means 34 and a charging receptacle 31 for guiding an access to the automatic
charging means 30 (see Figures 9 and 10) and applying a charging power to a
battery 26 when charge level detecting means 26a detects that a charging level
of the battery 26 is decreased to below a predetermined level, so that an
30 ultrasonic receiver of an ultrasonic sensor 116 of the navigation sensor 23
receives an ultrasonic wave generated from an ultrasonic wave oscillator 150 of
the automatic charging means 30.

In the above construction, a filter such as a sponge and the like, which is adapted to pass air therethrough but filter off dirt, is interposed between the dirt collecting chamber 16 and the vacuum motor 8, so that the dust and dirt collected in the dirt collecting chamber 16 cannot be introduced into the vacuum motor 8, thereby preventing motor trouble. The battery 26 for supplying its charging power as a driving energy of the robot cleaner 1 is positioned above the air duct 14. The nozzles 10 connected to the air ducts 14 via the suction ducts 12 each is provided at its outer end with a pair of rollers 20 in order to prevent the suction ducts 12 from being damaged and drive the robot cleaner 1 smoothly when the robot cleaner 1 comes into collision with a wall of a room.

The driving means 5 of the invention will now be described with reference to Figures 4 and 5. Figure 4 shows a front of the driving means for the robot cleaner of the present invention, and Figure 5 shows schematically a turning conversion gear and turning conversion motor of the driving means of the invention.

The driving means 5 comprises straight driving means for moving the robot cleaner 1 forward or backward and turning conversion means for converting a turning direction of the cleaner into a left turn or a right turn in response to control signals output from an output port (OUT1) of the microprocessor 2.

The straight driving means comprises a first driving motor 50 rotating normally and reversely, a first worm 52 fixed to a rotating shaft 50a of the first driving motor 50, a first worm wheel 54 engaging with the first worm 52 for transmitting the rotation force of the first worm 52, a second worm wheel 56 engaging with the first worm wheel 54 for adjusting the rotative speed, and the driving roller 6 connected to a driving shaft 6a of the second worm wheel 56 and adapted to be rotated normally and reversely.

The turning conversion means comprises a turning conversion motor 58

rotating normally and reversely, a second worm 60 fixed to a driving shaft 58a of the turning conversion motor 58, a third worm wheel 62 engaging with the second worm 60, a first spur gear 64 concentrically attached to an underside of the third worm wheel 62 for adjusting the rotative speed, a turning
5 conversion gear engaging with the first spur gear 64 and fixed to a periphery of the bracket 59 for turning the bracket 59 clockwise and counterclockwise, and a ball bearing 67 interposed between a flange 62a of the bracket 59 and the bottom plate 4 of the cleaner 1 for permitting the bracket 59 to be turned smoothly.

10

In the construction of the above driving means 5, the number of gear teeth formed at the first worm wheel 54 is larger than that of the second worm wheel 56, and the number of gear teeth formed at the third worm wheel 62 is larger than that of the first spur gear 64. Also, direct current (DC) motors
15 may be used as the first driving motor 50 and the turning conversion motor 58.

The turning direction sensing means of the invention will now be described with reference to Figures 4, 6a and 6b. Figure 6a shows a section of the
20 turning direction sensing means and Figure 6b shows a magnetic needle and a reflection disc 76 of the turning direction sensing means in Figure 6a. The turning direction sensing means 38 is mounted on the bracket 59 of the driving means 5 and serves to determine whether the robot cleaner 1 has been precisely turned by sensing a turning angle of the turning conversion means
25 and outputting the determined result to an input port (IN5) of the microprocessor 2.

As illustrated in Figures 4, 6a and 6b, the turning direction sensing means 38 comprises a hermetic container 68 containing transparent oil or liquid, a
30 magnetic needle 72 for indicating the north pole and the south pole which is rotatably mounted by means of a central pin 70 supported in upper and lower supporters 70a of the hermetic container 68, a reflection disc 76 attached to

the magnetic needle 72 and rotatably supported by the central pin 70 which is attached with a plurality of triangular reflective mirrors 74 defining a circle shape, a condensing lens 78 attached to a top of the hermetic container for condensing light, and an optical sensor 82 mounted above the condensing lens 78 which is adapted to detect a turning angle of the driving means by emitting light to the reflection mirror 74 attached to the reflection disc 76 and receiving the reflected light via the condensing lens 78 and to output the detected data to the input port (IN5) of the microprocessor 2.

- 10 In the above-mentioned turning direction sensing means, when it is desired to divide a circumferential angle of the reflection disc 76 into angles of 10° , 360 reflective mirrors 74 are attached to the reflection disc 76 at a uniform interval. Also, when it is desired to divide the circumferential angle into angles of 10° , 36 mirrors 74 are attached to the disc 76. In the present
15 embodiment, 36 to 720 reflective mirrors 74 are attached to the reflection disc 76. The reason why the reflective mirrors 74 are shaped into triangle forms is that the clockwise and the counterclockwise turning of the robot cleaner 1 can be easily determined by the reflective mirrors 74.
- 20 More specifically, when the amount of light received in the optical sensor 82 of the turning direction sensing means 38 becomes smaller gradually and repeatedly while the optical sensor 82 emits light to the reflective mirrors 74 and receives the reflected light from the mirrors 74, the optical sensor 82 can determine that the robot cleaner 1 is turning counterclockwise because the
25 points of the triangular mirrors 74 face counterclockwise continuously. In contrast to above case, when amount of light received in the optical sensor 82 becomes larger gradually and repeatedly, the optical sensor 82 can determine that the robot cleaner 1 is turning clockwise.
- 30 Also, when the driving roller 6 is turned clockwise through 90° in case of the reflection disc 76 having 36 reflective mirrors 74, since the optical sensor 82 of the turning direction sensing means 38 is turned clockwise with respect to the

disc 76, the optical sensor 82 senses that the receiving light through the condensing lens 78 from the reflective mirrors 74 becomes larger repeatedly 9 times and outputs the sensed data to the input port (IN5) of the microprocessor 2 so as to permit the microprocessor 2 to determine whether
5 the cleaner 1 has been turned clockwise through 90°.

The floor condition sensing means of the invention will now be described with reference to Figures 7 and 8a-8b. Figure 7 shows the floor condition sensing means of the invention, Figure 8a shows an operation of the floor
10 condition sensing means at a depressed portion and Figure 8b shows an operation of the floor condition sensing means at a stepped portion.

As shown in the drawings, the floor condition sensing means 28 comprises a caster 24, a link member 88 which rotatably supports a central shaft 24a of the
15 caster 24 at its one end and is integrally formed with an enlarged ball portion 86 at the other end, a support member 90 which pivotally holds the ball portion 86 of the link member 88, an actuating cylinder 94 which is pivotally mounted at its middle portion on a pin 96 of a fulcrum 92 formed at the bottom plate 4, a coil spring 100 as a biasing means interposed between the
20 support member 90 and the actuating cylinder 94, an actuating rod 98 inserted in the actuating cylinder 94 and the coil spring 100 and fixed to the support member 90 which is adapted to be compressed when the caster 24 encounters a stepped portion, a connecting lever 104 pivotally mounted on a pin 102a of a stationary bracket 102 at its middle portion which is connected to the
25 actuating rod 98 at its one end, and a microswitch 106 which detects whether the caster 24 encounters a depressed portion and a stepped portion by the pushing action of the actuating cylinder 94 and the pivoting action of the connecting lever 104 and outputs the detected signal to an input port (IN4) of the microprocessor 2.

30

In the above-constructed floor condition sensing means, since the actuating cylinder 94 maintains its horizontal state by contact with a sustainer 108 in

case of a floor free from an uneven surface (such as a depressed portion or a stepped portion), as shown in Figure 7, the actuating rod 98 compresses the coil spring 100 by the connecting lever 104. In this state, although a contact lever 106a of the microswitch 106 is in contact with an upper end of the connecting lever 104, the contact lever 106a is disconnected from a contact 106b of the microswitch 106. That is, since the microswitch 106 does not detect an uneven surface of a floor to be cleaned such as a depressed portion or a stepped portion, the microswitch 106 does not output any signal to the input port (IN4) of the microprocessor 2. Therefore, the robot cleaner 1 continues its movement.

On the other hand, as shown in Figure 8a, when the caster 24 falls in a depressed portion of a floor while moving in the direction of arrow "P" in the drawing, the actuating cylinder 94 is separated from the sustainer 108 and rotated clockwise. At this time, the actuating rod 98 is biased rightward by a biasing force of the coil spring 100 and rotates the connecting lever 104 to be separated from the contact lever 106a, and at the same time a raised end of the actuating cylinder 94 comes into contact with the contact lever 106a and pushes the contact lever 106a upward. Hence, the contact lever 106a comes into contact with the contact 106b of the microswitch 106, so that the microswitch 106 outputs a signal indicating a presence of the depressed portion to the input port (IN4) of the microprocessor. In accordance with the signal, the microprocessor 2 senses the depressed portion of the floor and outputs a control signal to the driving means 5. Upon receiving the control signal, the driving means 5 drives the turning conversion motor 58 to cause the robot cleaner 1 to be turned.

Also, as shown in Figure 8b, when the caster 24 is caught on a stepped portion of a floor to be stopped suddenly while moving in the direction of arrow "T" in the drawing at a uniform speed, an inertia force in the direction of arrow "T" is exerted on coil spring 100. Hence, the actuating rod 98 is moved leftward against the coil spring 100 and thus the connecting lever 104

is rotated clockwise and pushes the contact lever 106a upward, so that the contact lever 104 comes into contact with the contact 106b of the microswitch 106. Subsequently, the microswitch 106 outputs a signal indicating a presence of the stepped portion to the input port (IN4) of the microprocessor. In accordance with the signal, the microprocessor 2 senses the stepped portion of the floor and outputs a control signal to the driving means 5. Upon receiving the control signal, the driving means 5 drives the turning conversion motor 58 to cause the robot cleaner 1 to be turned.

10 The navigation sensor of the invention will now be described with reference to Figures 9a and 9b. Figure 9a shows the navigation sensor according to an embodiment of the invention and Figure 9b shows the navigation sensor according to an embodiment of the invention and Figure 9b shows a deflective reflection collar in Figure 9a.

15 As shown in the drawings, the navigation sensor 23 comprises an ultrasonic sensor 116 which emits an ultrasonic wave in a moving direction, receives the reflected wave and outputs it to the microprocessor 2 in order to determine a moving distance of the robot cleaner 1, an optical sensor 118 which emits light, receives the reflected light and outputs it to the microprocessor 2 in order to determine a moving direction, a bracket 122 provided with the ultrasonic sensor 116 and the optical sensor 118, a protector 120 for accommodating the ultrasonic sensor 116 and the optical sensor 118, the deflective reflection collar 124 mounted on a lower end of the protector 120 which is adapted to reflect the light emitted from the optical sensor 118, and sensor driving means for rotating the ultrasonic sensor 116 and the optical sensor 118 mounted on the bracket 122.

20 The sensor driving means comprises a second driving motor 126, a third spur gear 128 fixed to a rotating shaft 126a of the second driving motor 126 for receiving the driving force of the second driving motor 126, a fourth spur gear 130 engaging with the third spur gear 128, and a driving shaft 132 fixed to the

centre of the fourth spur gear 130 and attached with the bracket 122. In this case, the second driving motor 126 may be a DC motor capable of rotating normally and reversely.

5 In the above-constructed navigation sensor, lead wires 134 of the bracket 122 and the optical sensor 118 are respectively connected to a pair of conductors 136a and 136b through the bracket 122 and the driving shaft 132. The conductors 136a and 136b are connected to contacts 140a and 140b through springs 138a and 138b respectively. The conductors 136a and 136b are also
10 connected to an input port (IN3) of the microprocessor 2.

The deflective reflection collar 125 is attached with 36 to 720 triangular reflective mirrors 124a at its inner circumference. Accordingly, when the deflective reflection collar 124 has 36 reflective mirrors 124a, an interval
15 between the adjacent reflective mirrors 124a indicates an angle of 10° . Also, when the collar 124 has 720 mirrors 124a, an interval between the adjacent mirrors 124a indicates an angle of 0.5° .

In operation of the navigation sensor 23, when the user operates the robot cleaner 1 by pushing a button on the control panel 22, an output port
20 (OUT4) of the microprocessor 2 outputs a control signal to the navigation sensor 23 to drive the second driving motor 126 and also outputs a control signal to the ultrasonic sensor 116 and the optical sensor 118. Upon driving the second driving motor 126, the driving force of the second driving motor
25 126 is transmitted to the third spur gear 128 via the rotating shaft 126a to cause the third spur gear 128 to be rotated. At the same time, since the fourth spur gear 130 engaging with the third spur gear 128 is also rotated, the driving shaft 132 fixed to the centre of the fourth spur gear 130 is rotated. At this time, since the driving shaft 132 is attached with the bracket 122 having
30 the ultrasonic sensor 116 and the optical sensor 118, the ultrasonic sensor 116 and the optical sensor 118 emit an ultrasonic wave and light and receive the reflected wave and light, respectively while being rotated. Subsequently, the

ultrasonic wave sensor 116 and the optical sensor 118 output the reflected wave and light to the input port (IN3) of the microprocessor 2, so that the microprocessor 2 determines a distance to an obstacle and a direction of the obstacle on the basis of the reflected wave and light and then its output port
5 (OUT1) outputs a control signal to the driving means 5 in order to cause the robot cleaner 1 to be moved safely.

The automatic charging means for charging the battery of the robot cleaner according to the invention will now be described with reference to Figures 10
10 and 12. Figure 10 shows the robot cleaner which has been moved to the automatic charging means, Figures 11a and 11b shows a procedure in which the robot cleaner approaches the automatic charging means and then a plug of the robot cleaner is connected to the charging receptacle, which are taken along the line I-I of Figure 10, and Figure 12 shows an enlarged section of the
15 circle P of Figure 11b.

As shown in the drawings, the automatic charging means 30, which has an alternating current applying plug 160, comprises an ultrasonic wave oscillator 150 which emits an ultrasonic wave so as to inform the robot cleaner 1 of its
20 location during operation of the robot cleaner 1, a magnet sensing sensor 152 disposed under the ultrasonic wave oscillator 150 which is adapted to detect a line of magnetic force generated from the magnet 32 of the robot cleaner 1, a magnet 154 spaced from the magnet sensing sensor 152 which generates a line of magnetic force in order to cause the robot cleaner 1 to be precisely moved
25 to the charging position, a direct current applying plug 156 which is adapted to be plugged in the charging receptacle 31 of the robot cleaner to charge the battery 26 when the robot cleaner 1 approaches the charging position, and a holding rail 158 formed at a bottom panel 29 which prevents the robot cleaner 1 from being moved when the direct current applying plug 156 is
30 plugged in the charging receptacle 31 of the robot cleaner 1.

In the above automatic charging means, it is needless to say that the automatic

charging means 30 has a rectifier circuit for converting the alternating current from the AC applying plug 160 into a direct current, and for charging the battery 26.

5 As shown in Figure 12, the direct current applying plug 156 is fixed to an actuating rod 160a of a solenoid 160 at its base end 156a so as to be actuated by the solenoid 160. A coil spring 162 is inserted on the plug 156 and disposed between the base end 156a and a side wall 30a of the automatic charging means 30 so that the coil spring 162 causes the plug 156 to be
10 separated from a conductor 31a of the charging receptacle 31 when the battery 26 is completely charged. The conductor 31a of the receptacle 31 is electrically connected to the battery 26 by means of wiring (not shown).

15 A procedure for charging the battery 26 of the robot cleaner 1 will now be described.

The ultrasonic wave oscillator 150 of the automatic charging means 30 always emits an ultrasonic wave as long as the robot cleaner 1 is operated. When a charging voltage on the battery 26 is decreased below a predetermined level
20 during operation of the robot cleaner 1, an operation of an ultrasonic wave generator of the ultrasonic sensor 116 of the navigation sensor 23 is stopped and only the ultrasonic wave receiver is operated under the control of the microprocessor 2. Therefore, the ultrasonic wave receiver of the ultrasonic wave sensor 116 receives the ultrasonic wave emitting from the ultrasonic
25 wave oscillator 150 of the automatic charging means 30 and outputs its signal to the input port (IN3) of the microprocessor 2. Then, the microprocessor 2 determines the location of the automatic charging means 30 in response to the input signal and outputs a control signal to the driving means 5 through its output port (OUT1) in order to cause the robot cleaner 1 to be moved
30 toward the automatic charging means 30.

As the robot cleaner 1 approaches the automatic charging means 30, as shown

in Figure 11a, the magnet sensing sensor 34 of the robot cleaner 1 receives the magnetic force emanating from the magnet 154 of the automatic charging means 30 and outputs its signal to an input port (IN6) of the microprocessor 2. The microprocessor 2 outputs a driving control signal to the driving means 5 in response to the magnetic signal to cause the robot cleaner 1 to be moved in the direction of arrow "S" of Figure 11a, so that the robot cleaner 1 is precisely located in order to permit the battery 26 of the robot cleaner 1 to be charged, as shown in Figure 11b. In Figures 11a and 11b, the magnet sensing sensor 152, the plug 156 and the magnet 164 of the charging means 30, and the corresponding magnet 32, the receptacle 31 and the sensor 34 of the robot cleaner 1 are shown as being arranged horizontally for a better understanding.

The precise condition of the robot cleaner 1 for charging the battery 26 can be obtained only when the magnet sensing sensor 152 of the automatic charging means 30 and the magnet sensing sensor 34 of the robot cleaner 1 face the magnet 32 of the robot cleaner 1 and the magnet 154 of the automatic charging means 30 respectively so that the magnet sensing sensors 152 and 34 receive the corresponding magnetic forces respectively.

When the robot cleaner 1 is precisely located with respect to the automatic charging means 30, as shown in Figure 11b, the driving roller 6 of the robot cleaner 1 is prevented from being moved backwards by the holding railing 158. Therefore, the robot cleaner 1 cannot be pushed backwards although the direct current applying plug 156 of the automatic charging means 30 is inserted into the charging receptacle 31 of the robot cleaner 1 against the coil spring 162 by the actuation of the solenoid 160. As a result of that, the direct current applying plug 156 of the charging means 30 is positively connected to conductor 31a of the charging receptacle 31, thereby permitting the battery 26 to be completely charged.

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Since the power to the solenoid 160 is shut off after the battery 26 is completely charged, the direct current applying plug 156 is biased to the left,

when looking at Figure 12 by the restoring force of the coil spring 162. Accordingly, the plug 156 is electrically disconnected from the conductor 31a of the receptacle 31.

5 When the battery 26 is charged during a cleaning operation of the robot cleaner 1, it is needless to say that the microprocessor 2 outputs data regarding that portion of the floor which has been cleaned, that is, the data of a distance and a direction of cleaned floor which are input from the ultrasonic wave sensor 116 and the optical sensor 118 of the navigation sensor 23 by this time
10 to the memory 3 through its input and output ports (I/O) so as to store the data in the memory 3.

Therefore, after the battery is completely charged, the robot cleaner 1 can return to the discontinued cleaning location of the floor and then again carry
15 out its cleaning operation.

Figure 13 shows an initial operation of the robot cleaner according to the invention. The robot cleaner 1 of the invention does not clean a floor but memorizes only the structure of the floor during its initial circulation. Then,
20 the microprocessor 2 compares the structure with its cleaning programs previously stored in the memory 3 of the microprocessor 2 to select that program which is most similar to the structure and carries out the cleaning operation according to the selected program.

25 In other words, the microprocessor 2 determines the structure of the floor through the navigation sensor 23, the driving means 5 and the floor condition sensing means 28, and compares data of the determined structure with the data previously stored in the memory 3 in order to select the most efficient cleaning program.

30

Figure 14 shows a path for a cleaning operation of the robot cleaner of the invention. The robot cleaner 1 moves along the parallel to walls of the room

without cleaning operation during its initial circulation. During this circulation, the robot cleaner 1 memorizes a structure and a size of the room in the microprocessor 2 by detection of the navigation sensor 23, and compares the data of the structure of the room memorized in the microprocessor 2 with the data previously stored in the memory 3 to select the program most similar to the structure. Therefore, the robot cleaner 1 can carry out a cleaning operation according to the selected program.

A procedure for the initial operation of the robot cleaner of the invention will now be described with reference to Figure 15.

Figure 15 shows a flowchart exhibiting the procedure for the initial operation of the robot cleaner of the invention. In the drawing, the letter "S" means a step.

First, when the user pushes the button on the control panel 22 of the robot cleaner 1 in order to operate the cleaner 1, the robot cleaner 1 is initialized at a step S1. Then, operation proceeds to a step S2, where the second driving motor 126 is driven and the navigation sensor 23 is operated to cause the ultrasonic wave sensor 116 to emit an ultrasonic wave and to receive the reflected wave. The reflected wave is output to the input port (IN3) of the microprocessor 2. Also, the optical sensor 118 emits light, receives the reflected light and outputs it to input port (IN3) of the microprocessor 2.

At a step S3, the microprocessor 2 determines a distance to an obstacle on the basis of the wave data received in the ultrasonic sensor 116 and determines a direction of the obstacle on the basis of the light data received in the optical sensor 118. In accordance with the determined distance and the determined direction, the microprocessor 2 outputs a control signal to the driving means through its output port (OUT1) to cause the robot cleaner 1 to be moved to the cleaning start location closest to the present location.

At a step S4, the turning conversion motor 58 of the turning conversion means is driven to cause a moving direction of the driving roller 6 to be parallel to a wall so that the robot cleaner 1 can move along the wall.

5 Subsequently, whether or not the turning conversion of the robot cleaner 1 has been correctly accomplished is determined at a step S5. Otherwise stated, the optical sensor 82 of the turning direction sensing means 38 mounted on the bracket 59 of the driving means 5 emits light to the reflective mirrors 74 attached to the reflective disc 76, detects the reflected light from the reflective
10 mirrors 74 through the condensing lens, and outputs the detected signal to the input port (IN5) of the microprocessor 2. On the basis of the detected light signal, the microprocessor 2 determines whether the driving means has been turned through a required angle.

15 When the microprocessor 2 determines that the turning conversion of the robot cleaner 1 has been correctly accomplished in the step S5, that is, if Yes, the operation proceeds to a step S6 where the turning conversion motor 58 of the driving means 5 is stopped.

20 At a step S7, the first driving motor 50 of the straight driving means is driven to cause the robot cleaner 1 to be moved forward along the wall.

At a step S8, whether or not an obstacle is present in front of the robot cleaner 1 is determined by the navigation sensor 23. When an obstacle is
25 present in front of the cleaner, that is, if Yes, the operation proceeds to a step S10 after the turning conversion motor 58 of the driving means 5 is driven to cause the robot cleaner to be turned. On the other hand, when no obstacle is present in front of the robot cleaner 1, that is, if No, the operation directly proceeds to the step S10 where the optical sensor 15 of the turning direction
30 sensing means 38 emits light to the reflective mirrors 74, receives the reflected light data, and outputs it to the input port (IN5) of the microprocessor 2. On the basis of the received data, the microprocessor 2 determines whether the

robot cleaner 1 maintains its normal straight movement.

At the step S10, when the normal straight movement of the robot cleaner 1 is not maintained, that is, if No, the operation proceeds to a step S11 where the
5 output port (OUT1) of the microprocessor 2 outputs a control signal to the driving means 5 to correct the deviation of the robot cleaner 1. At the step S10, when the normal straight movement is maintained, that is, if Yes, the operation proceeds to a step S12.

10 When the robot cleaner 1 approaches a next wall during the normal straight movement, the turning conversion motor 58 of the driving means is driven, so that the robot cleaner 1 is turned right through 90° to be positioned parallel to the next wall at the step S12. Then, the microprocessor 2 inputs data of the moved distance and the turned angle at a step S13. Thereafter, the
15 operation proceeds to a step S14 where the robot cleaner 1, which has been turned by using the turning direction sensing means 38 of the driving means 5 at the step S12, moves straight in the turned state.

During this straight movement, the optical sensor 118 of the navigation sensor
20 23 continuously emits light forward and senses the reflected light in order to determine whether the robot cleaner is normally moved without a deviation. At the same time, the robot cleaner 1 detects data of a distance to a next wall through the ultrasonic wave sensor 116 and outputs it to the input port (IN3) of the microprocessor 2. The microprocessor 2 determines the distance to the
25 next wall on the basis of the input data and outputs a driving control signal of the distance to the driving means 5.

Subsequently, the operation proceeds to a step S15 where the robot cleaner 1 is turned through a right angle with respect to the wall and determines
30 whether a projected portion is present on the wall. When a projected portion is not present, that is, if Yes, the operation returns to the step S12 and then the steps S12 and S15 are thus repeatedly performed. When a projected

portion is not present on the wall at the step S15, the robot cleaner 1 is continuously driven to collect various data of the room to be cleaned.

That is, the microprocessor 2 inputs the data of the moved distance, the positions and turning directions at which the robot cleaner 1 has been turned while the robot cleaner 1 repeats the above-mentioned operation and then the robot cleaner 1 returns to the initial start location. At this time, the microprocessor 2 compares the input data with the various programs previously stored in the memory 3 and selects the program most similar to the structure of the room.

A procedure for a cleaning operation of the robot cleaner according to the invention will now be described with reference to Figure 16. Figure 16 shows a flowchart exhibiting a procedure for a cleaning operation of the robot cleaner.

First, the robot cleaner 1 performs the circulation operation in order to memorize the structure of the room at the step S1 in accordance with the flowchart of Figure 15. Thereafter, at a step S2, the microprocessor 2 selects the most effective cleaning program from the cleaning programs previously stored in the memory 3 on the basis of the data of the structure of the room obtained during the initial circulation operation (i.e., during step S1).

Therefore, the robot cleaner 1 carries out a cleaning operation along the cleaning path shown in Figure 14 in accordance with the cleaning program selected at the step S2. More specifically, the output port (OUT1) of the microprocessor 2 outputs a control signal to the first driving motor 40 of the driving means 5 so as to cause the first driving motor 50 to be driven. The rotating force of the first driving motor 50 is transmitted to the driving roller 6 through the first worm 52, the first and second worm wheels 54 and 56 and the driving shaft 6a, so that the robot cleaner 1 is moved parallel to the wall and along the cleaning path shown in Figure 14. During this movement, the

vacuum motor 8 is driven so that dust and dirt on the floor is sucked into the nozzle 10 of the suction duct 12 and collected in the dirt collecting chamber 16 through the air duct 14. In this case, since the filter 18 is interposed between the vacuum motor 8 and the direct collecting chamber 16, the dirt
5 collected in the dirt collecting chamber 16 cannot be introduced into the vacuum motor 8 by means of the filter 18.

When the robot cleaner 1 approaches the opposite corner as shown in Figures 13 and 14, the ultrasonic wave sensor 116 and the optical sensor 118 of the
10 navigation sensor 23 sense the front wall and output corresponding data to the microprocessor 2. Then, the microprocessor 2 determines the presence of the obstacle and thus outputs a control signal to the turning conversion motor 58 of the driving means 5 through its output port (OUT1) to cause the turning conversion motor 58 to be driven, so that the turning conversion motor 58
15 rotates the driving roller 6, thereby causing the robot cleaner 1 to be turned clockwise. More specifically, upon driving the turning conversion motor 58, the second worm 60 is rotated clockwise. Accordingly, the third worm wheel 62 engaging with the second worm 60 and thus the first spur gear 64 fixed to the third worm wheel 62 are rotated counterclockwise, so that the turning
20 conversion gear 66 engaging with the first spur gear 64 is rotated clockwise. Since the bracket 59 fixed in the turning conversion gear 66 is also rotated clockwise by the clockwise rotation of the turning conversion gear 66, the driving roller 6 supported by the bracket 59 is turned clockwise through an angle of 90°.

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Thereafter, the microprocessor 2 outputs a control signal to the first driving motor 50 so that the robot cleaner 1 moves by a predetermined distance (that is, a width between adjacent cleaning paths). At this point, as the first driving motor 50 is rotated, the rotating force of the first driving motor 50 is
30 transmitted to the driving roller 6 through the first worm 51, the first and second worm wheels 54 and 56 and the driving shaft 6a, so that the driving roller 6 is rotated to cause the robot cleaner 1 to be moved straight.

After the robot cleaner 1 has been moved by the predetermined distance, the microprocessor 2 again outputs a turning control signal through its output port (OUT1) to cause the turning conversion motor 58 to be rotated clockwise. As the turning conversion motor 58 is rotated clockwise, the third worm 62 and the first spur gear 64 are rotated counterclockwise and thus the turning conversion gear 66 is rotated clockwise. Accordingly, since the bracket 59 is rotated clockwise through an angle of 90° , the robot cleaner 1 will be positioned in the direction opposite to the initial portion of the robot cleaner.

10

Then, the microprocessor 2 outputs a control signal to the first driving motor 50 to cause the robot cleaner 1 to be moved straight. During this straight movement, dust and dirt on the floor is sucked into the nozzle 10 and collected in the direct collecting chamber 16.

15

In the above operation, whether the robot cleaner 1 is precisely turned left or right can be determined by counting up the number of the reflective mirrors 74 attached to the reflection disc 76 which have been rotated during the turn. That is, the optical sensor 82 of the turning direction sensing means 38 emits light to the reflective mirrors 74 attached to the reflection disc 76 and receives the reflected light through the condensing lens 78 during the turn. At this time, when the robot cleaner 1 is turned clockwise, the amount of light received in the optical sensor 82 is small at the beginning and is gradually increased repeatedly because the reflective mirrors 74 are arranged such that the points of the mirrors 74 face counterclockwise. Therefore, the microprocessor 2 determines the turned angle by counting up the repeated fluctuation times of the amount of light (that is, the number of mirrors). On the other hand, when the robot cleaner 1 is turned counterclockwise, the amount of light received in the optical sensor 82 is larger at the beginning and is gradually decreased repeatedly. Therefore, the microprocessor 2 determines the turned angle by counting up the repeated fluctuation times of the amount of light (that is, the number of mirrors).

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25
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Thereafter, the operation proceeds to a step S4 where the microprocessor 2 determines whether a depressed portion or a stepped portion (i.e., an abnormal portion) is present on the floor during the cleaning operation. In the step S4, when a depressed portion or a stepped portion is not present on the floor in a moving direction of the robot cleaner 1, that is, if No, the robot cleaner 1 returns to the step S3 and then carries out the cleaning operation while repeatedly performing the steps S3 and S4. On the other hand, when an abnormal portion is present on the floor in the moving direction, that is, if Yes, the robot cleaner 1 proceeds to a step S5.

10

At the step S5, since the caster 24 of the floor condition sensing means 28 is operated as described with reference to Figures 8a and 8b, the microswitch 10b is turned on. Then, the microprocessor 2 outputs a control signal to the turning conversion motor 58 through its output port (OUT1) to cause the turning conversion motor 58 to be driven at a step S6. In the step S6, as the turning conversion motor is driven, the second worm 60 connected to the motor 58 via the rotating shaft 58a is also rotated. The rotating force of the second worm 60 is transmitted to the turning conversion gear 66 through the third worm wheel 62 and the first spur gear 64. hence, the bracket 59 fixed in the turning conversion gear 66 is rotated, so that the driving roller 6 is turned, thereby causing the moving direction of the robot cleaner 1 to be converted. Thereafter, the operation proceeds to a step S7 where the first driving motor 50 and the vacuum motor 8 are driven under the control of the microprocessor 2 to carry out a continuous cleaning operation.

25

During the above-described cleaning operation, the charge level detecting means 26a continuously detects the charge level of the battery 26 and outputs the detected data to the input port (IN1). At a step S8, when the microprocessor 2 determines that the charging voltage of the battery 26 has decreased to below a predetermined level, that is, if Yes, the operation proceeds to a step S9 where the ultrasonic wave sensor 116 and the optical sensor 118 of the navigation sensor 23 detect the existing position of the robot

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cleaner 1 and output the data of the position to the input port (IN3) of the microprocessor 2. At this time, the operation of the oscillating circuit of the ultrasonic wave sensor 116 is stopped under the control of the microprocessor 2 to cause the emission of ultrasonic wave from the ultrasonic wave sensor 116 to be interrupted while only the receiving circuit of the ultrasonic sensor 116 is operated to receive an ultrasonic wave generating from the ultrasonic wave oscillator 150 of the automatic charging means 30 and to output the received data to the input port (IN3) of the microprocessor 2. Accordingly, the microprocessor 2 determines the position of the charging means 30 on the basis of the data.

Then, at a step S10, the microprocessor 2 output a control signal corresponding to the determined position of the charging means 30 to the turning conversion motor 58 and the first driving motor 50 of the driving means 5, so that the robot cleaner 1 is turned from its moving direction and moved to the position of the charging means 30, as shown in Figures 10 to 11b. At this time, since the vacuum motor is not operated, dust and dirt is not sucked into the nozzle 10 of the suction duct 12.

After the robot cleaner 1 has been moved to the vicinity of the charging means 30, the operation proceeds to a step S11. At the step S11, the magnet sensing sensor 34 of the robot cleaner 1 detects the line of magnetic force generated from the magnet 154 of the automatic charging means 30 and then the microprocessor 2 outputs a control signal corresponding to the detected line to the turning conversion motor 58 of the driving means 5 through its output port (OUT1) to cause the robot cleaner 1 to be moved in the direction of arrow of Figure 11a. When the robot cleaner 1 is precisely located at the charging position, the operation proceeds to a step S11. At this time, since the magnet sensing sensor 34 of the robot cleaner 1 directly detects the magnetic force generated from the magnet 154 of the charging means 30 while the magnet sensing sensor 152 of the charging means 30 directly detects the magnetic force generated from the magnet 32 of the robot cleaner 1, the

solenoid 160 of the charging means 30 is applied with power. Therefore, the actuating rod 160a of the solenoid 160 and thus the plug 156 are moved outward against the coil spring 162. As the plug 156 is projected outward, the plug 156 comes into contact with the conductor 31a of the receptacle 31 of the robot cleaner 1, thereby permitting the battery 26 to be charged with direct current.

When the battery 26 is completely charged in the step S11, the robot cleaner 1 returns to the step S7 and performs repeatedly the steps S7 to S11. That is, the robot cleaner 1 moves to the position at which the cleaning operation is interrupted (particularly, the position at which the charging voltage of the battery 26 is decreased to below the predetermined level) and then again carries out the cleaning operation at the position.

As apparent from the above description, the robot cleaner of the present invention can carry out a cleaning operation by itself while moving on a floor. Also, when the charging voltage of the battery of the robot cleaner is decreased to below a predetermined level during the cleaning operation, the robot cleaner moves to the automatic charging means and then charges the battery by itself. Thereafter, the robot cleaner returns to the interrupted position, at which the charging voltage of the battery had decreased below the predetermined level, and again carries out the cleaning operation.

Accordingly, since the robot cleaner of the invention does not need to be constantly monitored by the user, any one can easily use the robot cleaner in a cleaning operation.

In the above embodiment, although the robot cleaner has been described in such a way that the rotating shaft 50a of the first driving motor 50 is connected to the first worm 52 and the first worm 52 is engaged with the first worm wheel 54 to cause the rotating force of the driving motor 50 to be transmitted to the driving roller 6, the invention is not be limited to this embodiment, for example, it is possible to use spur gears having different

numbers of gear teeth instead of the first worm 52 and the first worm wheel 54.

In addition, although the robot cleaner has been described in such a way that
5 the rotating shaft 58a of the turning conversion motor 58 is connected to the
second worm 60 and the second worm 60 is engaged with the third worm
wheel 62 to cause the rotating force of the turning conversion motor 58 to be
transmitted to the turning conversion gear 66, the invention is not limited to
this embodiment, for example, it is possible to use spur gears having different
10 numbers of gear teeth instead of the second worm 60 and the third worm
wheel 62.

Reference is further directed to UK patent application no. 9323741.0, from
which this application has been divided.

CLAIMS

1. A robot cleaner comprising:
5 a cleaner body;
driving means provided at a bottom of the cleaner body and in contact with a floor for moving the cleaner body in a predetermined direction; and
direction sensing means integrally mounted on the driving means for sensing a moving direction of the driving means, said direction sensing means having a
10 housing, a central shaft rotatably and vertically supported in the housing, a disc vertically and rotatably fixed to the central shaft at its centre and provided with a permanent magnet, a plurality of reflective means defining a circle provided on a surface of the disc, and means mounted on the housing for sensing a turned angle of the driving means by emitting light to the
15 reflective means and receiving and counting up the reflected lights.
2. A robot cleaner in accordance with claim 1, wherein said driving means comprises straight driving means for moving the robot cleaner forward and backward and turning conversion means for converting a turning
20 direction of the cleaner into a left turn or a right turn.
3. A robot cleaner in accordance with claim 2, wherein said straight driving means comprises a first driving motor for rotating normally and reversely, a first worm connected to a rotating shaft of the first driving motor,
25 a first worm wheel engaged with the first worm, a second worm wheel engaged with the first worm wheel for adjusting a rotating speed, and a driving roller connected to a driving shaft of the second worm wheel and adapted to rotate normally and reversely.
- 30 4. A robot cleaner in accordance with claim 2 or 3, wherein said turning conversion means comprises a turning conversion motor for rotating normally and reversely, a second worm connected to a rotating shaft of the turning

conversion motor, a third worm wheel engaged with the second worm, a first spur gear concentrically fixed to an underside of the third worm wheel for increasing a rotating speed, a turning conversion gear fixed to a periphery of a bracket supporting the driving roller and engaged with the first spur gear for turning the bracket left and right, and a ball bearing interposed between a flange of the bracket and a bottom plate of the cleaner body for permitting the bracket to be smoothly rotated.

5. A robot cleaner in accordance with claim 1, wherein said driving means comprise a first driving motor for rotating normally and reversely, a first worm connected to a rotating shaft of the first driving motor, a first worm wheel engaged with the first worm, a second worm wheel engaged with the first worm wheel for adjusting a rotating speed, a driving roller connected to a driving shaft of the second worm wheel and adapted to rotate normally and reversely, a turning conversion motor rotating normally and reversely, a second worm connected to a rotating shaft of the turning conversion motor, a third worm wheel engaged with the second worm, a first spur gear concentrically fixed to an underside of the third worm wheel for increasing a rotating speed, a turning conversion gear fixed to a periphery of a bracket supporting the driving roller and engaged with the first spur gear for turning the bracket left and right, and a ball bearing interposed between a flange of the bracket and a bottom plate of the cleaner body for permitting the bracket to be smoothly rotated.

6. A robot cleaner in accordance with claim 5, wherein the number of gear teeth formed at the first worm wheel is larger than that of gear teeth formed at the second worm wheel.

7. A robot cleaner in accordance with claim 5 or 6, wherein the number of gear teeth formed at the third worm wheel is larger than that of gear teeth formed at the first spur gear.

8. A robot cleaner in accordance with any one of the preceding claims, wherein said direction sensing means comprises a hermetic housing, a magnetic needle received in the hermetic housing and rotatably supported by upper and lower supporters of the hermetic housing at its central shaft for
5 indicating the north and south poles, a reflection disc rotatably fixed to the central shaft of the magnetic needle and provided with a plurality of reflective mirrors thereon, a condensing lens attached to an upper portion of the hermetic housing for condensing light, and an optical sensor adapted to emit
light to the reflective mirrors on the reflection disc and to receive the reflected
10 light for detecting a turned angle of the driving means and outputting it to a microprocessor.

9. A robot cleaner in accordance with claim 8, wherein said hermetic housing contains transparent oil or liquid therein.

15

10. A robot cleaner in accordance with claim 8 or 9, wherein each of said reflective mirrors has a triangular shape.

11. A robot cleaner in accordance with any one of claims 8 to 10, wherein
20 said reflection disc is provided with between 36 and 360 triangular reflective mirrors thereon for detecting a clockwise or a counterclockwise turn of the driving means.



Application No: GB 9716990.8
Claims searched: 1-11

Examiner: Andrew Bartlett
Date of search: 15 September 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:
UK CI (Ed.O): G3N (NGA3, NGA4, NG2); G1A (ABAX, AEAX);
H4D (DLFR, DLFJ)
Int CI (Ed.6): G05D 1/02 & 1/03; G01B 21/00; G01S 3/789, 15/02, 15/88, 17/02 &
17/88
G01D 5/32, 5/34, 5/347 & 5/36
Other: Online:- WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage			Relevant to claims
A	GB 2262997 A	(Samsung)	See figures 4-7	1 at least
A	GB 1412582	(Marriott)	See whole document	1 at least
A	EP 0387710 A2	(Standard Electric)	See figures 1 & 2	1 at least

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